GLIDER WING LOADING SPECTRUM IN WINCH-LAUNCHING, GROUND RUN AT AEROTOWING AND IN LANDING

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Introduction

The measurements in flight of the glider wing loading spectrum made in Poland on the SZD-51-1 "Junior" glider, as related to the maneuvering loads in aerobatics were reported at the OSTIV Congress in Benalla, 1988.

The further measurements taken during winch-launching, ground run at aerotowing take-offs and in landings form a continuation of the previous investigation.

The measuring system and data processing were described in the Benalla report. In this report, the results obtained in the above-mentioned operation cases are described and discussed. The reason for the separate analysis of the winch-launching and ground run is that the basic load factor n 1, is not equal to, contrary to the other in-flight situations where it is. (e.g. interthermal flight, final glide) or nearly so (e.g. circling in thermal, aerotowing) due to the contribution of tailforce, bank angle, etc.

Presentation of data

The wing loading spectrum for the cases of winch-launching and ground run, where the load factor changes with time, is presented in the form of

$$n_w = f(t^*) \text{ diagram}$$

where:

$$n_w = \frac{P_w}{W - W_w} \text{ – wing load factor}$$

P_w – wing lift

W – all-up weight of glider

W_w – wing weight

$$t^* = \frac{t}{t_{tot}} \text{ – relative time}$$

t – fraction of time

t_{tot} – total time of the observation

The wing load factor "n_w" contains two components:

$$n_w = n_{w_0} + \Delta n_w$$

where:

n_{w_0} = basic load factor

Δn_w = incremental load factor (positive or negative as shown on Fig. 1).

The frequency of the load cycles, as the second data for $n_w = f(t^*)$ diagram, is listed in the tables and related to 100 observations. The table values for each "t^*" value are the cumulative cycle amounts.

Such a form of data presentation is convenient for the case of basic load factor being not constant in time.

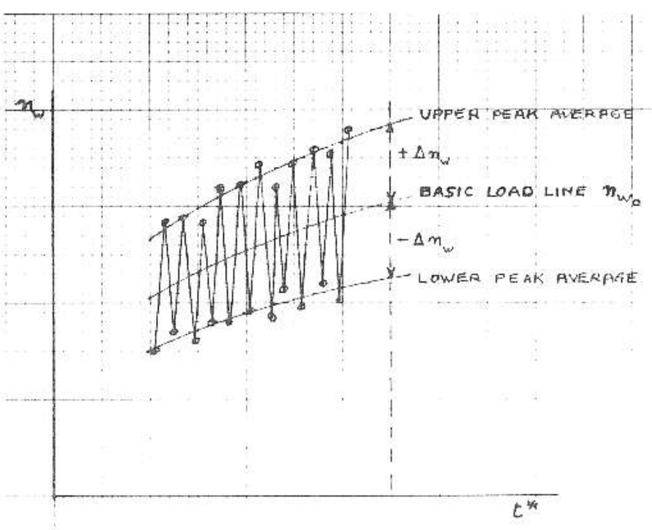

Figure 1.

Winch-launching

The time "t_{tot}" of each launch is the time from the beginning of the glider motion up to the moment of cable release, that is the time of the total take-off procedure.

The variation of the basic load factor versus time is shown on Figure 2.

At the start point the basic load factor value is:

$$n_{w_0} = \frac{-W_w}{W - W_w}$$

since the wing is loaded by its own weight, acting downwards (minus value).

With the increasing airspeed, the wing lift force P_w reaches the value of W_w and the wing becomes "weightless" at $t^* =$ 0,025 to 0.05 (depending on the wind velocity). Then, the basic load factor increases to balance the weight and cable force components. Its maximum value appears at the steep part of the climbing path and reaches 2,1 to 2,7 (also depending on the wind velocity) at time t^* of about 0,55.

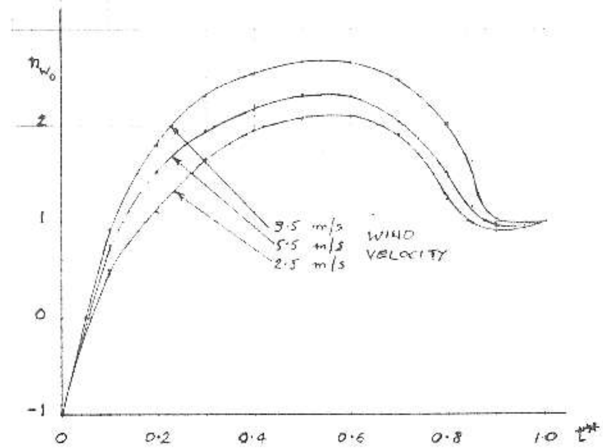

Figure 2.

The measurements were taken at the wind velocities of 2.5, 5.5 and 9.5 m/s; maximum basic load factor versus the wind velocity is shown on Figure 3.

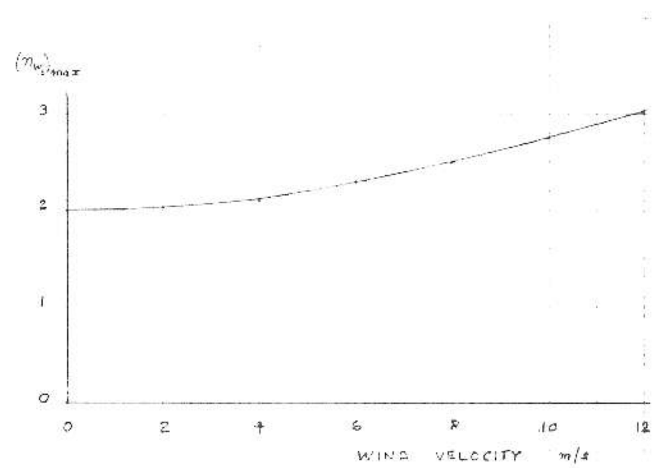

Figure 3.

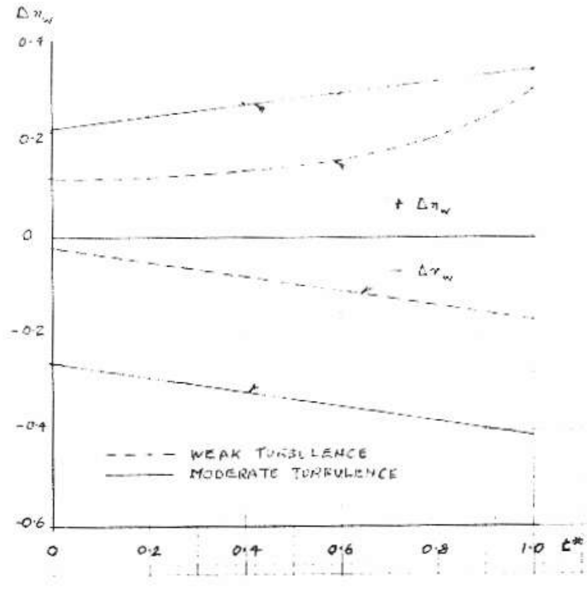

Figure 4.

The incremental load factors Δn_W (positive and negative) were measured in weak and moderate turbulence (Figure 4). The values of incremental load factors increase with time, since the air turbulence is greater at higher altitude.

The frequencies of peak loading are listed in Table I, as related to 100 launchings.

TABLE I: Loading cycles for 100 winch-launchings

After time t*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
H_{100}	1800	2800	3075	3303	3306	3527	3887	3947	4977	5543

Ground run at aerotowing

The variation of basic load factor with time is shown on Figure 5. Initially negative due to the wing's own weight, the value passes through zero ("weightless" wing) at t* = 0.16 and becomes 1,0 at the end of the observed section when the glider is airborne.

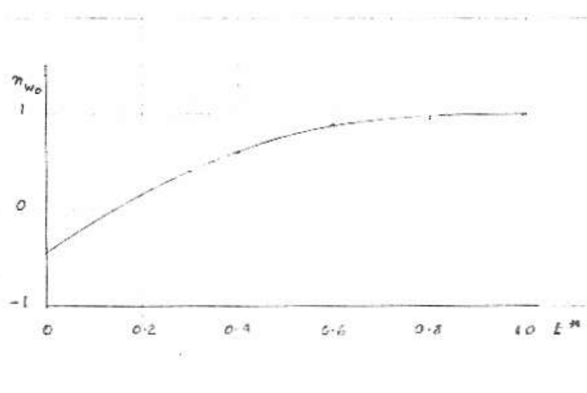

Figure 5.

The values of incremental load factors for grass and concrete surfaces are shown on Figure 6. The influence of the surface condition is easy to recognize. It was interesting to find that the negative incremental load factor for grass reaches its maximum at t* = 0,6.

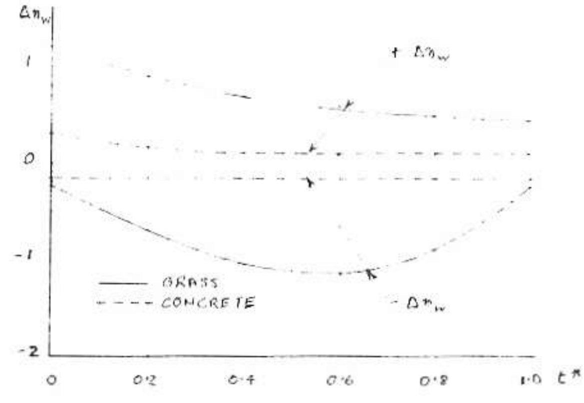

Figure 6.

TABLE II: Loading cycles for 100 ground runs in aerotowing

After time t*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
H_{100}										
grass	507	1027	1454	1874	2307	2707	3100	3487	3867	4167
concrete	1000	1860	2690	3430	4130	4800	5570	6370	7090	7840

The frequencies of peak loading, again related to 100 ground runs, are contained in Table II. The concrete surface produces a greater number of loading cycles, but of a considerably lower load level, due to the very small unevenness uniformly distributed along the runway, contrary to the case of grass.

Ground run at landing

The diagram of basic load factor versus time, shown on Figure 7, has the inverted sequence when compared with that for take-off. The load factor decreases from 1.0 at touch down

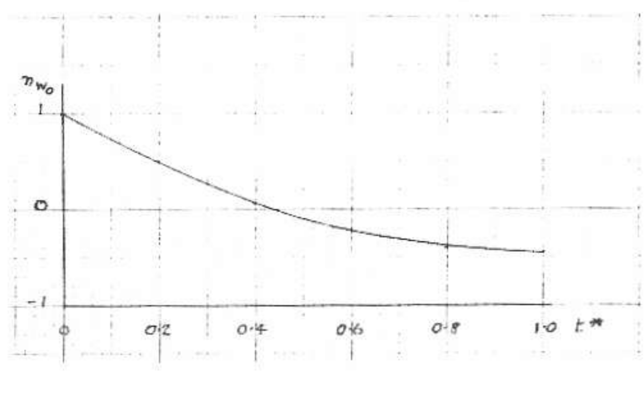

Figure 7.

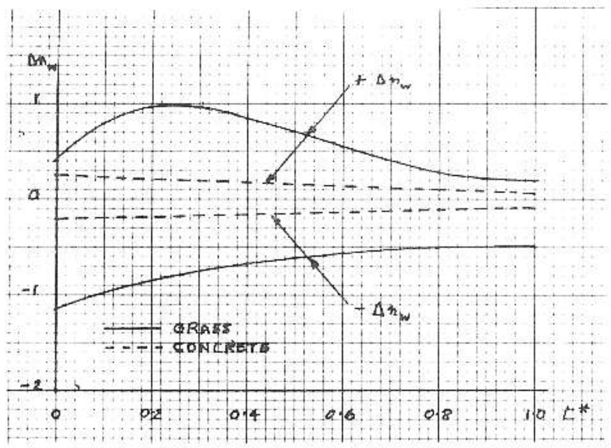

Figure 8.

and passes zero at t* = 0,46. The incremental load factors for grass and concrete surfaces are shown on Figure 8. The positive incremental load factor on grass reaches its maximum at t* = 0,25.

The frequencies of peak loading, related to 100 landings, are contained in Table III.

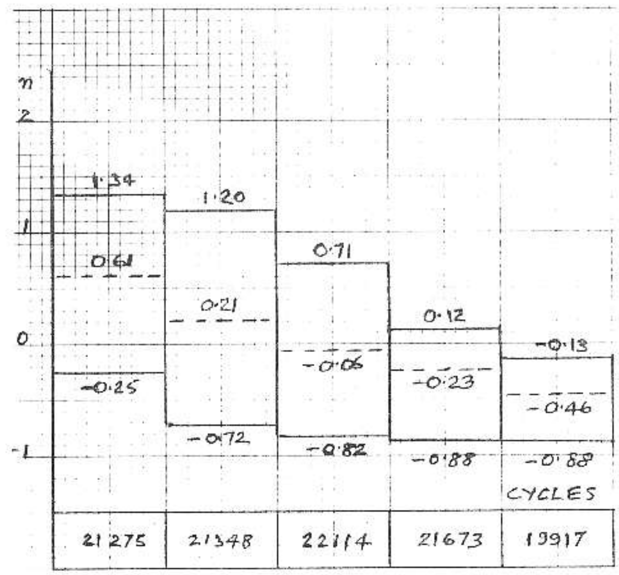

Figure 10.

TABLE III: Loading cycles for 100 ground runs at landing

After time t*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
H_{100}										
grass	482	919	1346	1800	2310	2800	3309	3800	4264	4710
concrete	1130	2130	3310	4270	5430	6730	7930	9280	10590	11870

Conclusions

The spectrum of the wing loading in winch-launching and ground run at take off and landing, which when compared with the other operation situations, differs due to the basic load factors being a function of time. This fact does not permit presenting the spectrum, as usually, in the form of cummulative line of load factor versus frequency with the basic load $n_0 = 1$, or nearly so.

Spectrum shape as used for fatigue test program

For the purpose of programming the wing ground fatigue tests, the continuous load spectrum is simulated by the stepped one, as commonly practiced today.

For each load step the basic as well as the maximum and minimum load factor values have been established as the main parameters of the test program.

Figure 9 shows such a program for winch-launching of the SZD-51-1 "Junior" glider in the weak and moderate turbulence. The number of cycles for each loading level has been established for the life-time of 1000 flying hours, according to the assumed pattern of glider operation. This life-time includes 2560 winch-launches.

Figure 10 shows the wing fatigue test program for aerotowing take-offs in the 1000 flying hours life-time. This includes to 1780 take-offs as related to the pattern of SZD-51-1 "Junior" glider operation.

Wing fatigue test program for landings is shown on Figure 11. The number of cycles covers the operational pattern of 2318 landings of SZD-51-1 "Junior" glider within the 1000 flying hours life-time program.

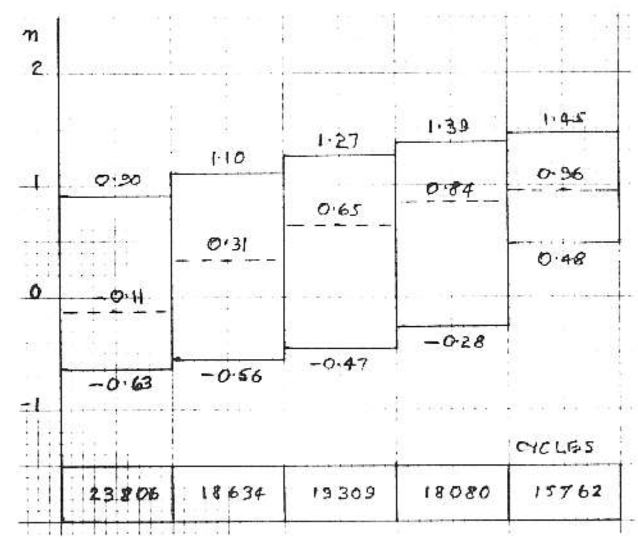

Figure 11.

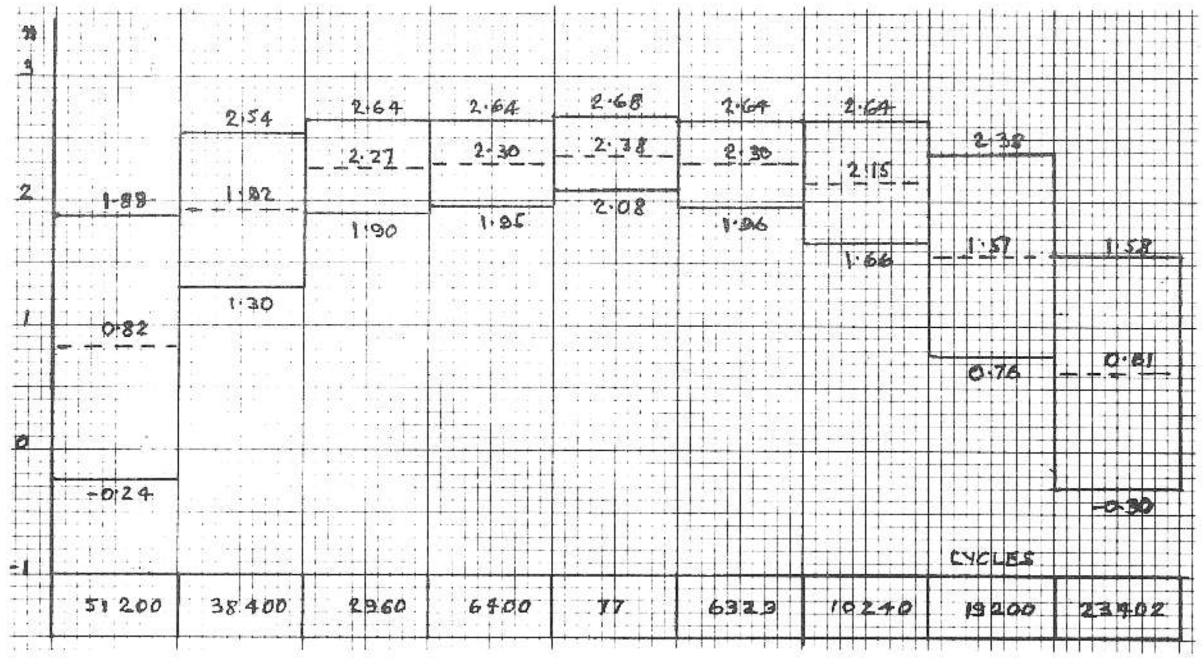

Figure 9.

For the purpose of describing the spectrum the relative time "t*" has been introduced to permit:

- showing the basic load factor as a function of time,
- avoiding the influence of different total time "t_{tot}" of the tested loading cases (due to variations in winch power, length of the towing cable or the type of towing plane, condition of airfield surfaces, etc.).

As a consequence of such an assumption the incremental load factors have also been presented as the function of time "t*".

The load peaks have been smoothed to the average lines of maximum and minimum, and these averaged values have been used in designing the fatigue test program for SZD-51-1 "Junior" glider.

The diagrams of basic load factor versus time permit following the shape of function of increasing lift in line with the increasing glider airspeed, or decreasing the lift with the decreasing airspeed for take-off and landing respectively.

The wing fatigue test program is, therefore, based on the different basic load factor for the particular load level and particular time sections.

The above spectrum data are understood as a part of the wide flight testing program aimed at producing practical material for designing the fatigue test program.

The next step, planned to be completed in the next year, is to record the load spectrum in aerotowing, circling in thermals, interthermal flights and final glides, as well as wave flying.

All these operational situations should be measured in the weak, moderate and especially in the strong turbulence.